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(12) # NEW EUROPEAN PATENT SPECIFICATION

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GB-A- 747 828
US-A- 3 365 618
US-A- 3 644 864
US-A- 3 673 538

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Description

This invention relates to thermistors for temperature sensing, particularly but not exclusively automotive engine temperature sensors.

Conventional automobile engines are water cooled and the water cooling system is arranged to operate under a pressure of between 3515 and 10545 kg/m^3 (5 and 15 lbs per square inch) and at a temperature just below 90°C. A temperature sensor is issued which senses the temperature of the cylinder block, which is very close to the water temperature and which provides an electrical signal representative of temperature to provide an indication of the temperature on a temperature gauge or display on the vehicle dashboard.

Under normal conditions the temperature gauge displays a fluctuating reading, dependent upon factors such as ambient temperature, speed, load etc. Because of tolerances in the engine and cooling system, as well as the sensor and gauge system, the 'normal' temperature for a particular vehicle will vary widely. This has caused considerable concern to vehicle owners, leading to return of the vehicle under warranty. As the vehicle could genuinely be running at an abnormally high or low temperature it must be checked and this is costly.

Conventionally the temperature sensor comprises a thermistor which has a negative temperature coefficient of resistance. It is known from Patent US-A-3365618 to modify the response of a single thermistor by adding other thermistors. The device described in US-A-3365618 is designed to have a lagging response to rapid temperature rises so as to "anticipate" a high temperature which will cause permanent damage, before the damage actually takes place, thereby extending the normal working temperature range of for example an electric motor. This patent specification provides widely differing characteristics for the sensor dependent upon the rate of temperature rise.

Patent GB-A-747828 relates to electric thermometers which is designed for measuring temperatures of lubrication or cooling fluids in thermal motors and more particularly those arranged on board motor cars or aircraft. It has for its object to increase the reading accuracy and to provide a specific construction with a sensor housing including a thermistor element in the form of a disc, a surrounding electrically insulating sheet, a heat conducting housing and a resilient member for exerting pressure on the contact faces of the disc. The free space within the housing is filled with a dielectric fluid of high heat conductivity.

Patent US-A-3673538 describes a thermistor switch and is aimed at making switching temperatures more accurate in a switching thermistor device, so avoiding expensive and precise control circuitry necessary with similar prior art devices. Such an arrangement is designed to work where normal or expected operating temperatures lie on steeply-sloping parts of the curve of the thermistor device, to ensure precise operation.

Of the above-described prior art only GB-A-747828 relates to sensing and indicating temperatures. The other U.S. Patents are essentially switching devices and they are concerned with improving the accuracy of such devices or providing a special response which will extend the operating temperature range of the electric motor before switching occurs to cut off the electrical supply. Neither of these U.S. documents is capable of or intended for controlling an indicator device.

It is an object of the present invention to overcome the difficulties eluded to above with regard to sensing temperatures, particularly vehicle engine temperatures and is an improvement over the type of sensor generally disclosed in Patent GB-A-747828.

According to one aspect of the present invention there is provided a thermistor temperature sensing and indicating system as defined in claim 1.

In a particular application the sensor is suitable for sensing the temperature of a vehicle engine, the predetermined temperature lying in the range of 60°C to 120°C, preferably 80°C to 95°C; typically the temperature is 88°C.

Preferably the device comprises a first NTC thermistor connector electrically in series with the parallel combination of a second NTC thermistor and a PTC thermistor, the three thermistors being in good heat transfer relationship with each other.

For some applications the sensor can comprise a second parallel combination of a third NTC and a second PTC thermistor, the second combination being connected electrically in series with the series combination and in good thermal contact.

In order that the invention can be clearly understood reference will now be made to the accompanying drawings in which:-

Fig. 1 shows diagrammatically a thermistor composite for temperature sensing in an automotive engine, according to an embodiment of the present invention, together with the temperature characteristic,

Figs. 2A to 2E show various physical arrangements of the composite of Fig. 1,

Fig. 3 shows the temperature characteristics of parts of the composite of Figs. 1 and 2,

Fig. 4 shows further temperature characteristics of parts of and the whole composite of Figs. 1 and 2.

Fig. 5 shows schematically a system for temperature sensing in an automotive engine employing a thermistor composite of Figs. 1 and 2,

Fig. 6 shows diagrammatically a thermistor composite according to a second embodiment of the invention and the temperature characteristic of it,

Fig. 7 shows the complete composite of Fig. 6 in a physical arrangement,

Fig. 8A shows a thermistor composite according to another embodiment of the invention,

Figs. 8B and 8C show the temperature characteristics of parts of the whole of, respectively, the composite of Fig. 8A,

Figs. 8D, 8E and 8F show three different physical arrangements of the composite shown in Fig. 8A,

Fig. 9 shows an engine temperature sender incorporating a thermistor composite according to an embodiment of the invention.

Fig. 10 shows the temperature characteristic of a thermistor composite according to an embodiment of the invention and explains the effect of self-heating, and

Fig. 11 shows alternative physical arrangements of the composite of Fig 8A.

Referring to Fig. 1, the thermistor composite suitable for engine temperature sensing comprises an NTC thermistor 1, and a parallel combination of a PTC thermistor 2 and a second NTC thermistor 3. The overall temperature characteristic is negative as shown in Fig. 1, the plateau P being caused by thermistors 2 and 3.

As shown in Fig. 3 thermistors 2 and 3 have positive and negative characteristics 2a and 3a, which combine to give an overall characteristic 4 shown in broken line.

The effect here and in the embodiment of Figs. 6 and 7, is that as each PTC thermistor switches, its parallel NTC thermistor is brought into contact, thereby changing the characteristic ho a new curve.

Now, referring to Fig. 4 this characteristic 4 modifies the characteristic 1a of the NTC thermistor 1 to give the characteristic C with the plateau P, shown in broken line in Fig. 4 and full line in Fig. 1.

The plateau is centred on 88°C which is the normal operating temperature of the vehicle engine. The edges of the plateau are situated at approximately 80°C and 95°C so that tolerances in the thermistor itself and in the system, and variations in the temperatures above and below 88°C, caused e.g. ambient temperature (winter or summer), speed of the vehicle and load (e.g. towing a caravan) will not take the temperature of the thermistor device outside the range 80°C to 95°C. Hence the temperature gauge in the vehicle will not register any change despite the tolerances and conditions described.

If however the engine temperature falls below or rises above the range 80°C to 95°C then this would arise from a fault condition or serious engine overload, and the temperature gauge will indicate the change.

An example of such a system is shown in Fig. 5. Referring to Fig. 5 a temperature gauge 10 for a vehicle is connected in series with a temperature sender 11 incorporating the thermistor composite of Fig. 2A mounted in an engine cylinder block 12. Power from the vehicle battery 13 via ignition switch 14 provides a current through the gauge 10 and the sensor 11. With the sensor cold the resistance is high as for example when the vehicle is first started. As the vehicle warms up the sensor resistance falls and more current passes through the gauge which in this embodiment is a bimetallic or moving iron device whose finger 10a moves as the current increases. As shown in Fig. 5 the indicator finger 10a has risen from the "COLD" end 10b of the scale 10c. When the engine reaches its normal running temperature of say 88°C the finger 10a will point at the "NORMAL" mark 10d. Because of the plateau P in the sensor characteristic C shown in Fig. 1, the finger will continue to point at the "NORMAL" mark despite the tolerances and temperature fluctuations referred to earlier. If the engine overheats through loss of coolant or overloading and the temperature rises above 95°C, the finger will move towards the hot zone 10c, entering the red sector at 115°C. Alternatively if the engine thermostat fails the engine may never reach the normal operating temperature range (80°C to 95°C) and the finger will not reach the "NORMAL" mark 10d on the scale, also indicating a fault condition (less serious of course than the overheating fault condition).

Alternatively the gauge or display 10 could have a simple scale of temperature in e.g. degrees Centigrade, yet nevertheless make use of the present invention for the particular temperature, in this case 88°C.

A particular form of construction for the sensor of Fig. 1 is shown in Fig. 2A and comprises a thermistor composite in which the thermistors are disc thermistors thermally and electrically bonded together using solder. The NTC thermistor 3 and the PTC thermistor 2 are electrically connected across their exposed faces 2b and 3b by a lead disc 7 (shown in Fig. 2B and later in Fig. 9). Fig. 2B shows one example of a temperature sender for a motor vehicle. The composite is mounted in a screw threaded plug 20 with a connecting tag 21. The plug is screwed into an appropriate hole in the cylinder head of the engine 12, as depicted in Fig. 5. In more detail the thermistor composite is resiliently compressed by a spring 22 between the lead connecting disc 7 and a lead disc 23 seated in the base of the plug 20. An insulating member 24 carrying the tag 21 is secured in and closes off the open end of the hole 25 in the plug. The body of the plug acts as the earth connection, being connected to the thermistor composite through the lead disc 23.

Fig. 2C shows an alternative construction to that shown in Fig. 2A. Referring to Fig. 2C the composite comprises an NTC disc thermistor 41, a PTC "washer" shaped thermistor 42 with contact surfaces top and bottom and a second NTC disc thermistor 43 placed concentrically within the hole of thermistor 42. The unit is completed by means of a lead disc positioned both above and below this thermistor combination. In this format the unit is not soldered together as in Fig. 2A (although this could be employed if the mechanical contact proved inefficient) reliance being placed on spring 22 to provide pressure electrical and thermal contacts within the thermistor composite. The alternative, similar arrangement of a NTC washer with a small PTC disc placed in the hole is also envisaged as a practical solution in some cases. Otherwise the operation of the composite is the same as described with reference to Fig. 1.

A third form of construction is shown in Fig. 2D. Here the two half discs 2 and 3 of Fig. 2A are replaced by small NTC and PTC discs 52 and 53 soldered to the larger NTC disc thermistor 51, corresponding to thermistor 1 or 41 of Fig. 2A or 2C. This gives all components a form which is easier for auto-testing before assembly, although it is not too efficient in the use of available surface area needed to achieve the low resistance required. It is a useful embodiment for higher resistance applications.

Yet another construction is shown in Fig. 2E. The NTC thermistor 61 corresponding to thermistors 1, 41 and 51 of previous embodiments has a U-shaped metal clip 64 connected to its upper surface by solder or by mechanical pressure from spring 22. Between the arms of the "U" are the NTC and PTC thermistors 62 and 63, corresponding to thermistors 2 and 3, 42 and 43, 52 and 53 of previous embodiments. The arms are sprung against the sides of thermistors and solder may or may not be required. A second metal clip 65 of cruciform shape has its sprung legs held between the inner faces of the thermistors, with or without solder.

All the arrangements described in Figs. 2A, 2C, 2D and 2E are designed to be used in a temperature sender, basically as shown in Fig. 2B or in a modified version shown in Fig. 9 and to be discussed later.

Another embodiment of the present invention is shown in Figs. 6 and 7. Referring to these figures the thermistor sensor comprises five disc thermistors, three NTC thermistors 31, 33 and 34 and two PTC thermistors 32 and 25. These thermistors are bonded together to form a unitary structure as shown in Fig. 7. A copper disc 36 is bonded in the interface between thermistors 32 and 33 on the one hand, and 34 and 35 on the other hand. Alternatively an unbonded lead disc 36 could be used.

A similar disc could be applied bonded or unbonded to the exposed faces of thermistors 34 and 35 for external connection to be made. The characteristic for this thermistor composite is shown in Fig. 6 and it has two plateaus P1 and P2 centered on two different temperatures. For example plateau P1 could correspond to a "cold" condition in a system whereas plateau P2 corresponds to a hot condition, in each case the plateau having the compensation effect described earlier so that false or misleading conditions by an indicator are not given.

In the embodiment described, or in other embodiments and applications which can be readily appreciated, by selection of particular slope and resistance values for the NTC thermistors and plateau can be widened or narrowed and by selecting the differing switch points and resistances for the PTC thermistor(s) the position of the plateau can be changed. Low slope PTC thermistors and various other non-linear resistors can also be incorporated to modify the curve shape.

The mechanical arrangements for connecting-both thermally and electrically-described above are thought to be the best for the automotive environment, but various other methods will be possible and understood by those skilled in the art.

An alternative electrical format is shown in Fig. 8A. This format can give a similar resistance-temperature characteristic as the previously-described embodiment. NTC and PTC thermistors 71 and 72 (corresponding to thermistors 1 and 2 of Fig. 1) are connected in series and a third thermistor 73 which is an NTC thermistor, corresponding to thermistor 3 in Fig. 1, is connected in parallel with the series combination. For this format the series pair of 71 and 72 combine as shown in Fig. 8B and this connected in parallel with thermistor 74 combine to give the curve 74 shown in Fig. 8C. This final curve is very similar to the curve C of Fig. 4 with the plateau centred on the working normal engine temperature of 88°C. It differs in that the combination is always lower in resistance, particularly at higher temperatures, than NTC thermistor 3 of Fig. 1. This can be advantageous since this is the more critical part of the resistance-temperature curve for the application of vehicle engine temperature sensing.

The mechanical formats are shown in Figs. 8D, 8E and 8F. Fig. 8D comprises half discs 71 and 72 soldered together and edgewise to half disc thermistor 73.

Fig. 8E comprises disc thermistors 81 and 82 (corresponding to 71 and 72) housed within a washer-shaped thermistor 83 (similar to 73).

Fig. 8F comprises two "washer"-shaped thermistors 91 and 92 (equals 81 and 82) housing a single disc NTC thermistor 93 (equals 83).

All three configurations would be sandwiched between a pair of lead discs such as 7 and 23 described with reference to Fig. 2B.

The embodiment described in Figs. 2A, 2C, 2E and 8D, 8E and 8F can each be assembled without soldering the thermistor elements together. All the contact surfaces of the devices described in Figs. 2A to 2E and Figs. 8D to 8F would be silvered, or in the case of a PTC thermistor have an aluminium surface applied, but otherwise a purely mechanical assembly can be provided in a tubular insulting support, such as 102 to be described later with reference to Fig. 9, without soldering, relying on the pressure of a spring such as spring 22 in Fig. 2B, to make and maintain the necessary contacts inside the probe body plug 20 shown in Fig. 2B.

An example of a modified temperature sender is shown in Fig. 9. The screw threaded plug 101 contains a plastic tube 102 with the thermistor composite elements indicated generally by reference number 103 retained by lead washers 7 and 23 held by friction against the inside bore 104 of the tube, and a step 105 locating the thermistor composite just inside the lower end of the tube. The composite 103 can then be sold and transported as a sub-assembly within the tube 102 only, and finally assembled into body 101 elsewhere. When this is done and the spring 22 is applied, the composite 103 slides down, the spring pressure overcoming friction between the bore 104 and the lead washers 7 and 23 and the composite occupies the position shown in broken line and identified by reference numeral 103A. The top of the body 101 would then be closed with a cap 24 as indicated in Fig. 2B, with conductive lead out 21 from spring 22.

It is pointed out that the voltage applied to the measuring circuit may vary from a low, near zero value to the full battery value of 12 volts, depending on the precise circuit employed. For the higher applied voltages, self-heating of the thermistors will occur so that a temperature above the engine temperature will occur within the thermistor probe body. Thus the curve C shown in Figure 10 in dashed line represents the response of the complete probe under higher applied voltage, i.e. with thermistor self-heating, whereas curve C1 in Figure 10 in dot-dashed line represents output from the same thermistor composite under low, near zero, applied voltage. This difference in thermistor output under different temperature indicating circuit conditions must be allowed for in the design of the NTC/PTC thermistor combination in order to provide correct engine temperature indication. The measuring circuit in different vehicles may vary considerably according to the type of indicating meter employed and the measuring voltage applied. To match these variations together with variations in the 'normal' operating temperature of different engines the resistance of the composite will vary widely as will the resistance and temperature range of the plateau for example between 10 ohms at the plateau and 500 ohms at the plateau. The term 'plateau' in this specification is meant to include also a "hump" in the characteristic, i.e. the plateau may not be quite flat necessarily.

Two examples of the variations in resistance and temperature range of composites required for different engines are as follows:-

Example 1:
Petrol engine 6 cylinder

Resistance (ohms)	Temperature (probe)(°C)
112	120
170	104
170	96
240	80
630	60

Example 2:
Diesel engine

30	110
60	90
60	75
85	60

In all the thermistor arrangements described the thermistors are in good heat transfer relationship with each other either directly through direct surface to surface contact with each other, or in the case of Fig. 2E indirectly through the intermediary of metal clip parts. However an arrangement could be envisaged where the good thermal transfer is provided by the casing and/or by an oil filling only.

It will also be appreciated by those skilled in the art that both the NTC thermistors could be formed from an integral thermistor element so shaped that, with the addition of the PTC thermistor element the effect of three thermistors, two NTC and one PTC can still be achieved from the combination.

Examples of this are shown in Figs. 11A to 11C. In 11A NTC thermistors 66 and 67, corresponding to thermistors 1 and 3 in Fig. 1, are fabricated as an integral structure and so shaped ("L"-shaped in side view) that the PTC thermistor 68, corresponding to thermistor 2 in Fig. 1, can be used in the same way as the structure of Fig. 2A.

Figures 11B and 11C show similar integral structures for the two NTC thermistors for composite structures which have a washer shaped PTC and a small disc PTC respectively.

In general the normal operating temperature sensed for vehicle engines could be anywhere in the range 60°C to 120°C depending on the type of engine and the positioning of the sensor to the combustion chamber(s).

Claims

1. A temperature sensing and indicating system for a motor vehicle comprising a sensor for sensing the vehicle engine temperature, and a display device for giving a temperature indication wherein the sensor (11) comprises a three-thermistor

combination (1,2,3) including an NTC and a PTC thermistor, said combination having a plateau (P) in its resistance/temperature characteristic at the normal operating temperature, e.g. 88°C, of the engine (12) to compensate for expected tolerances inthe system and/or expected variations, in the normal temperature whereby to prevent a change in the indication (10,10a) which would otherwise be caused by such tolerances and/or variations, the resistance of the combination changing in the same sense with changes in temperature above and below said plateau.

2. A system as claimed in claim 1 characterised bythe sensor comprising a first NTC thermistor (1) connected electrically in series with the parallel combination of a second NTC thermistor (3) and a PTC thermistor (2).

3. A system as claimed in claim 1 or claim 2, characterised in that two of the thermistors (2b,3b,42,43,52,53,32,33,71,72) are located on one surface of the third thermistor (1,41,51, 31,73).

4. A system as claimed in claim 3, characterised in that said two thermistors (2b,3b) are each partdisc shaped.

5. A system as claimed in claim 3, characterised in that one (43) of said two thermistors surrounds the other (42).

6. A system as claimed in claim 1, characterised by the sensor comprising a first NTC thermistor (73) connected electrically in parallel with the series combination of a second NTC thermistor (71) and a PTC thermistor (72).

7. A system as claimed in any preceding claim characterised by the sensor being mounted in the bore of a carrier tube (102) from which the sensor can be at least partially removed by spring pressure (72).

8. A system as claimed in any preceding claim, comprising a housing adapted to be secured to the device whose temperature is to be sensed, the sensor (103) being mounted in the housing (101).

Patentansprüche

1. Temperaturfühler- und Anzeigesystem für ein Motorfahrzeug mit einem Temperaturfühler zur Messung der Fahrzeugmotortemperatur und mit einer Anzeigeeinrichtung zur Lieferung einer Temperaturanzeige, bei dem der Temperaturfühler (11) eine einen NTC- und einen PTC-Thermistor einschließende Drei-Thermistor-Kombination (1,2, 3) umfaßt, die ein Plateau (P) in ihrer Widerstands-/Temperatur-Charakteristik bei der normalen Betriebstemperatur, beispielsweise 88°C, des Motors (12) aufweist, um erwartete Toleranzen in dem System und/oder erwartete Abweichungen der Normaltemperatur zu kompensieren, so daß eine Änderung der Anzeige (10,10a), die anderenfalls durch derartige Toleranzen und/oder Abweichungen hervorgerufen werden könnte, verhindert wird, wobei der Widerstand der Kombination sich in der gleichen Richtung mit Änderungen der Temperatur oberhalb und unterhalb des Plateaus ändert.

2. System nach Anspruch 1,
dadurch gekennzeichnet, daß der Temperaturfühler einen ersten NTC-Thermistor (1) umfaßt, der elektrisch in Serie mit der Parallelkombination aus einem zweiten NTC-Thermistor (3) und einem PTC-Thermistor (2) geschaltet ist.

3. System nach Anspruch 1 oder 2,
dadurch gekennzeichnet, daß zwei der Thermistoren (2b,3b,42,43, 52,53,32,33,71,72) auf einer Oberfläche des dritten Thermistors (1,41,51,31, 73) angeordnet sind.

4. System nach Anspruch 3,
dadurch gekennzeichnet, daß die genannten zwei Thermistoren (2b,3b) jeweils teilscheibenförmig sind.

5. System nach Anspruch 3,
dadurch gekennzeichnet, daß einer (43) der genannten zwei Thermistoren den anderen (42) umgibt.

6. System nach Anspruch 1,
dadurch gekennzeichnet, daß der Temperaturfühler einen ersten NTC-Thermistor (73) umfaßt, der elektrisch parallel zur Serienkombination eines zweiten NTC-Thermistors (71) und eines PTC-Thermistors (72) geschaltet ist.

7. System nach einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet, daß der Temperaturfühler in der Bohrung eines Trägerrohres (102) befestigt ist, aus dem der Temperaturfühler zumindestens teilsweise durch Federdruck (72) herausbewegt werden kann.

8. System nach einem der vorhergehenden Ansprüche, mit einem Gehäuse, das an dem Bauteil befestigbar ist, dessen Temperatur zu messen ist, wobei der Temperaturfühler (103) in dem Gehäu-

se (101) befestigt ist.

Revendications

1. Système de détection et d'indication de température destiné à un véhicule à moteur, ce système comprenant un capteur destiné à détecter la température du moteur du véhicule, et un dispositif d'affichage destiné à donner une indication sur la température, dans lequel le capteur (11) comporte une combinaison de trois thermistances (1, 2, 3) comprenant une thermistance NTC (à coefficient négatif de température) et une thermistance PTC (à coefficient positif de température), la combinaison ayant un palier (P) dans sa courbe caractéristique résistance-température à la température normale de fonctionnement, par exemple à 88 °C, du moteur (12), afin que les tolérances prévues du système et/ou les variations prévues de la température normale soient compensées, si bien qu'une variation de l'indication (10, 10a) qui pourrait autrement être provoquée par ces tolérances et/ou variations soit supprimée, la résistance de la combinaison changeant dans le même sens que les variations de température audessus et au-dessus dudit palier.

2. Système selon la revendication 1, caractérisé en ce que le capteur comprend une première thermistance NTC (1), connectée électriquement en série avec la combinaison en parallèle d'une seconde thermistance NTC (3) et d'une thermistance PTC (2).

3. Système selon l'une des revendications 1 et 2, caractérisé en ce que deux des thermistances (2b, 3b, 42, 43, 52, 53, 32, 33, 71, 72) sont placées sur une première surface de la troisième thermistance (1, 41, 51, 31, 73).

4. Système selon la revendication 3, caractérisé en ce que les deux thermistances (2b, 3b) ont chacune la forme d'une partie de disque.

5. Système selon la revendication 3, caractérisé en ce que l'une (43) des deux thermistances entoure l'autre (42).

6. Système selon la revendication 1, caractérisé en ce que le capteur comprend une première thermistance NTC (73), reliée électriquement en parallèle avec la combinaison en série d'une seconde thermistance NTC (71) et d'une thermistance PTC (72).

7. Système selon l'une quelconque des revendications précédentes, caractérisé en ce que le capteur est monté dans le trou d'un tube de support (102) dont le capteur peut être retiré au moins partiellement par la pression d'un ressort (72).

8. Système selon l'une quelconque des revendications précédentes, comprenant un boîtier destiné à être fixé à un dispositif dont la température doit être détectée, le capteur (103) étant monté dans le boîtier (101).

Fig.1.

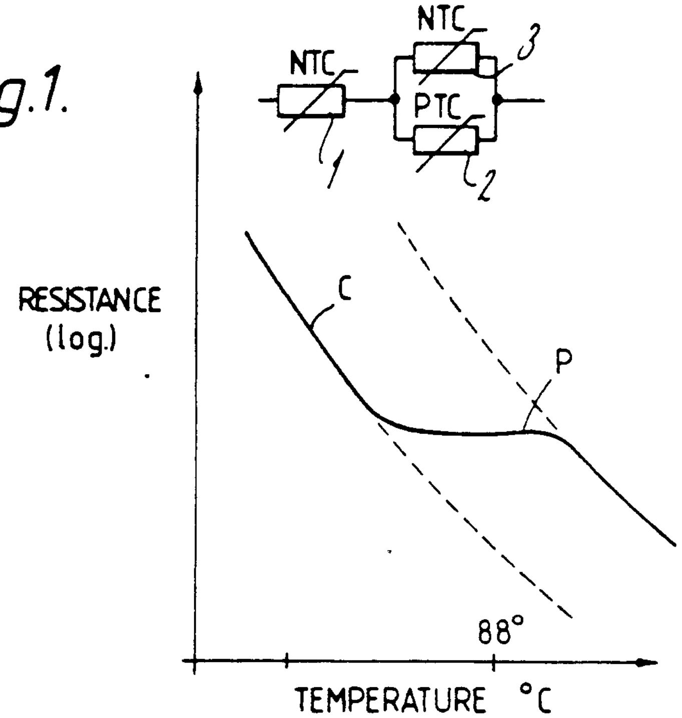

Fig.2A.

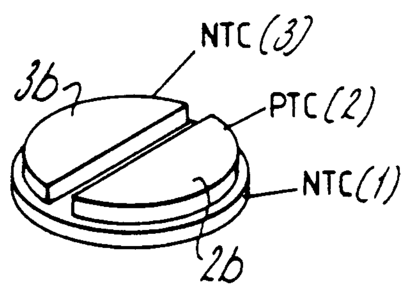

Fig.2B.

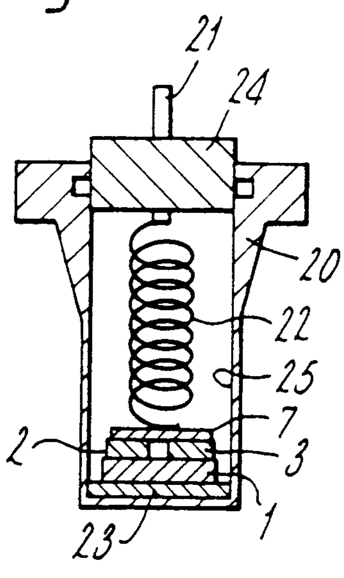

Fig.2C.

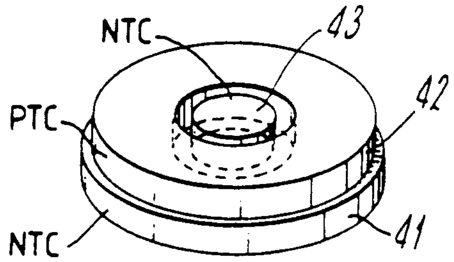

Fig.2D.

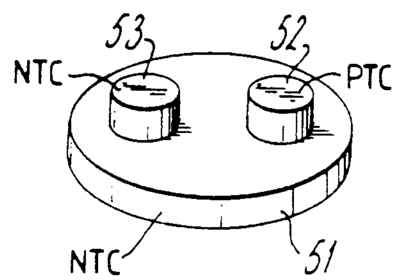

Fig.2E.

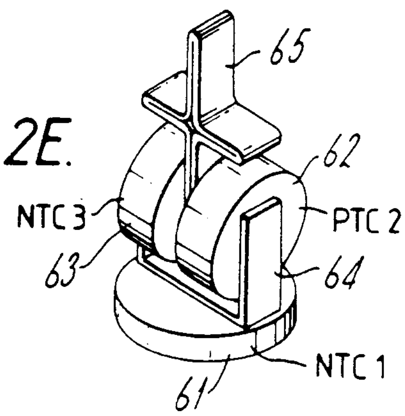

Fig.3.

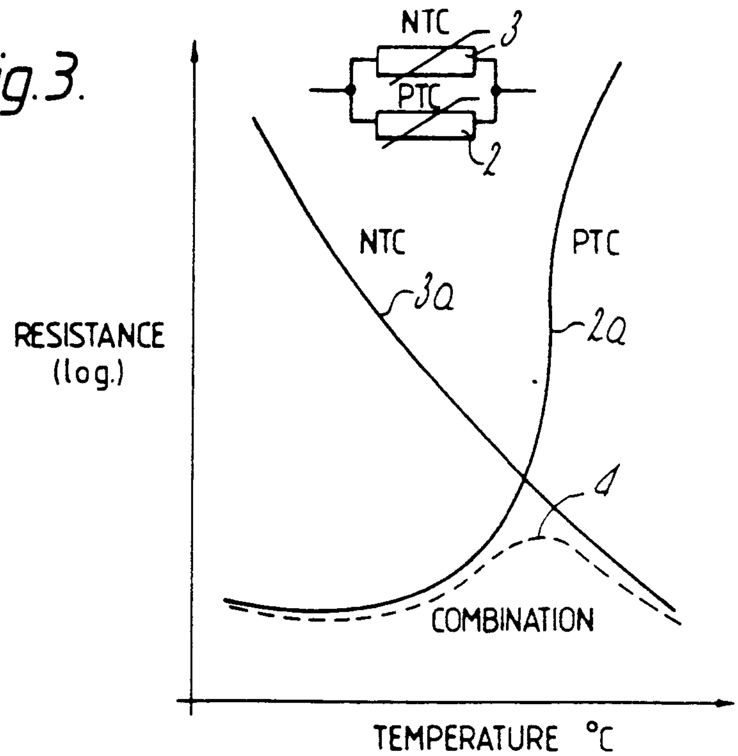
NTC
3
PTC
2
NTC
PTC
3a
2a
RESISTANCE
(log.)
4
COMBINATION
TEMPERATURE °C

Fig.4.

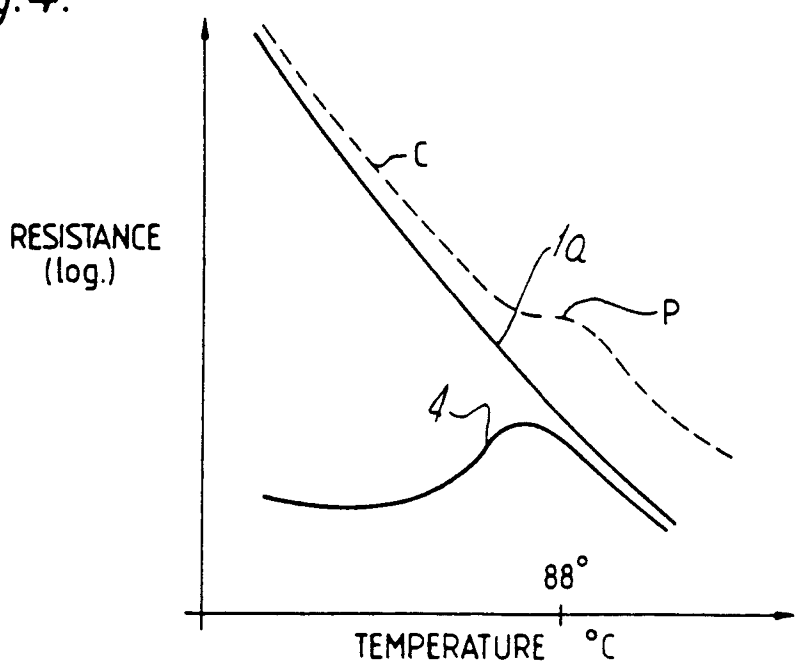
C
RESISTANCE
(log.)
1a
P
4
88°
TEMPERATURE °C

Fig. 5.

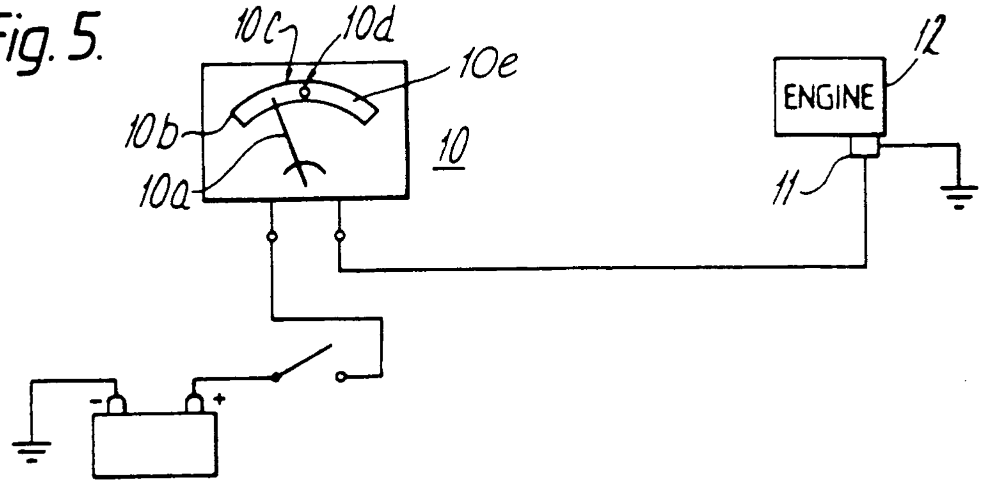

Fig.6.

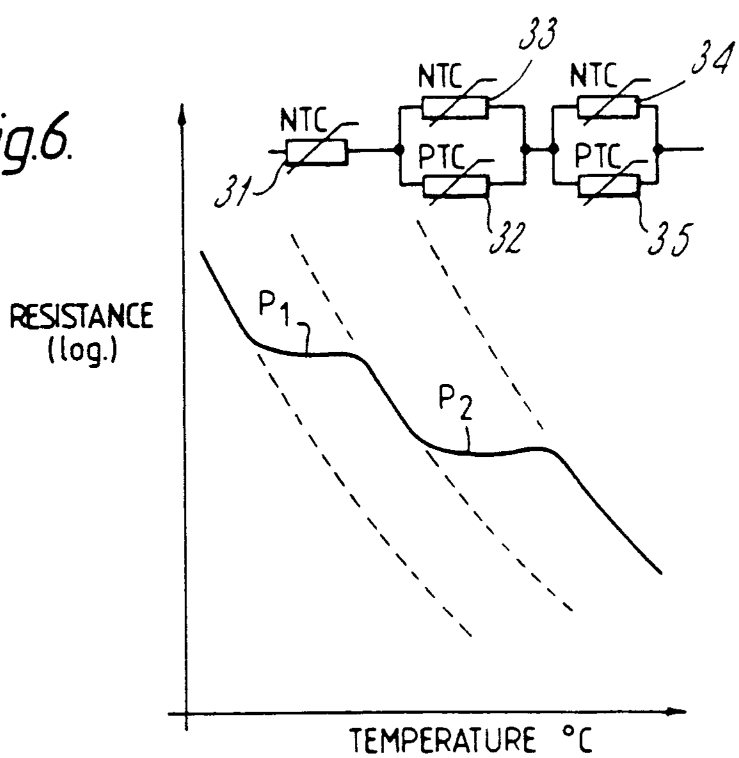

Fig.7.

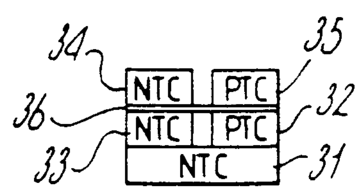

Fig.8A.

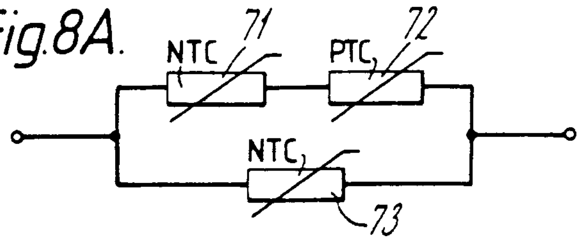

Fig.8D.

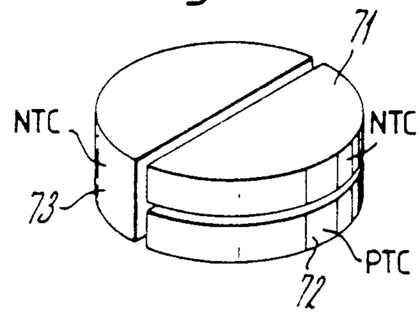

Fig.8B.

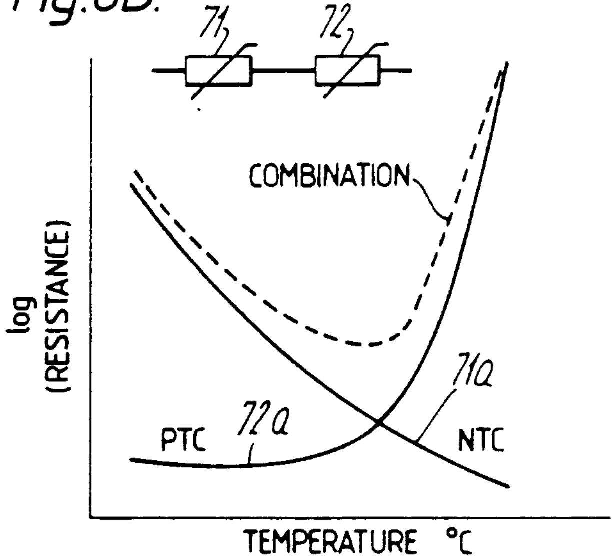

Fig.8E.

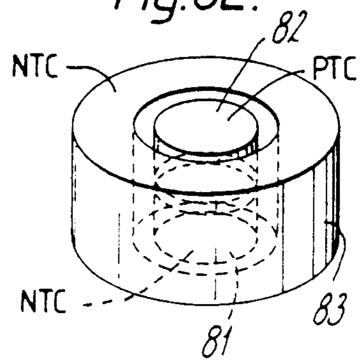

Fig.8C.

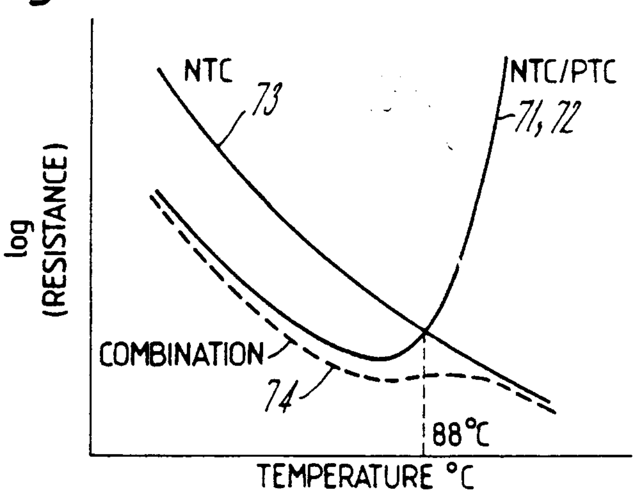

Fig.8F.

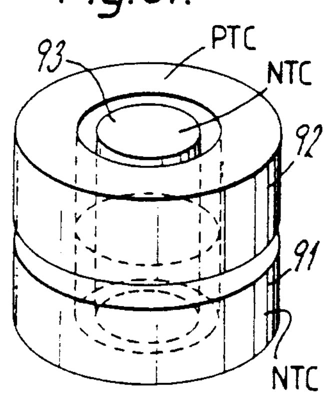

Fig.9.

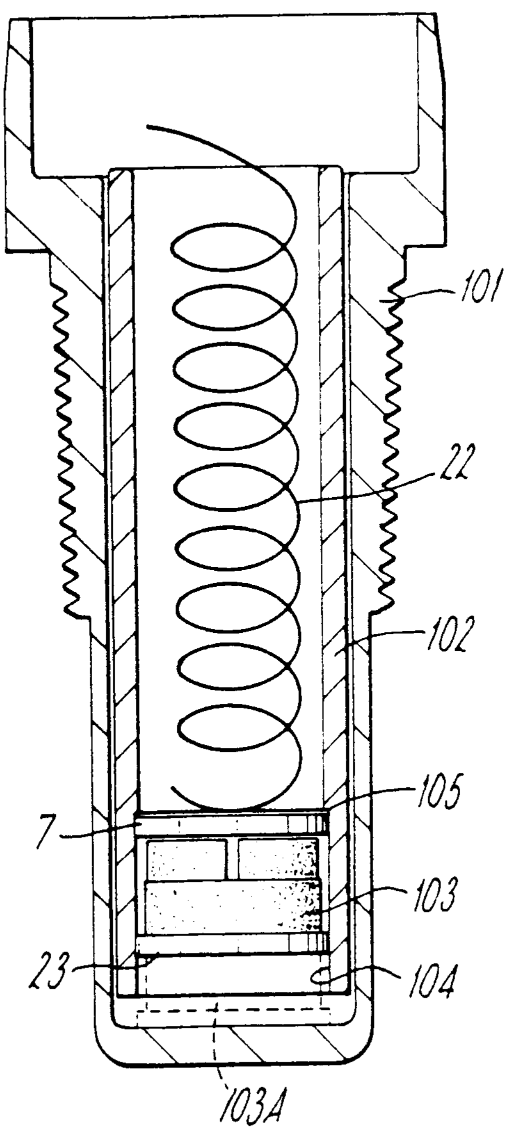

Fig.10.

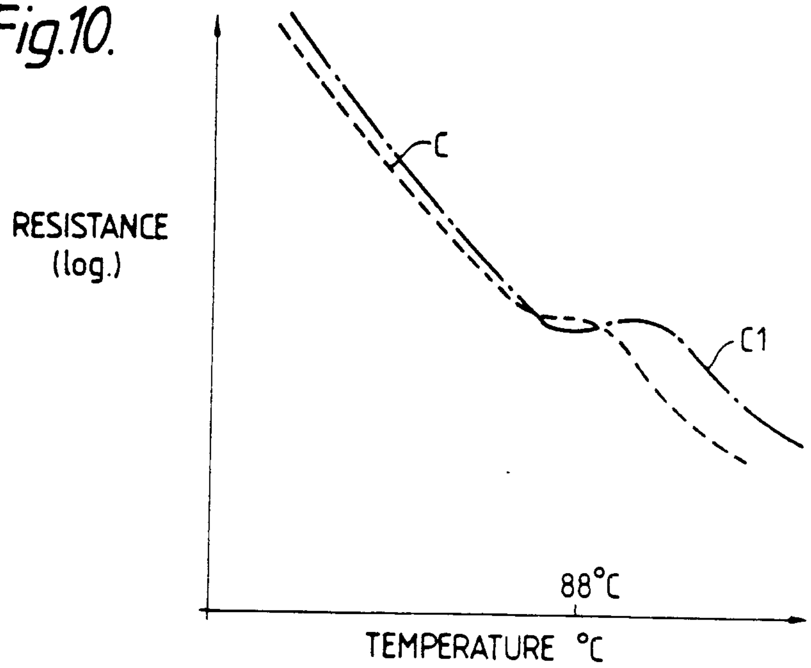

Fig.11A.

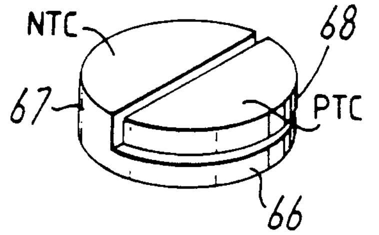

Fig.11B.

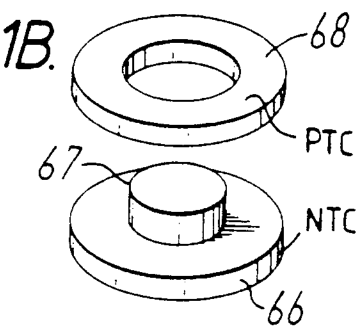

Fig.11C.